EVALUATION OF LT^3, ISV AND IN-SITU BIORECLAMATION SYSTEM

Throughput Through LT^3

The throughput for LT^3 is approximately 7 tons/hr for soils containing 20 percent moisture. The throughput rate will vary with moisture content of the soil.

The attached Tables 1 and 2 provide the summary of thermal desorption of volatiles, semivolatiles and Aroclor 1260 from two sites.

In-situ Vapor Extraction

A vapor-phase vacuum extraction system is effective in removing compounds that have Henry's Law Constant greater than 0.001. Compounds which have been effectively removed by vapor extraction include trichloroethene, trichloroethane, tetrachloroethene, and most gasoline constituents. Compounds which are less easily removed include trichlorobenzene, acetone, and heavier petroleum fuels.

Capping: A impermeable cap is used if the movement of the air towards the extraction vent is desired to be more redial than vertical. The radius of influence around the extraction vents extends when an impermeable vent is in place. The capping materials normally used for capping include plastic sheeting, clay, or asphalt.

The cost of clay liner will be approximately $2.50 to $3.00 per square feet.

In-situ bioreclamation:

The bioreclamation technique is used for treating zones of contamination by microbial degradation. The basic concept involves altering environmental conditions to enhance microbial catabolism or cometabolism of organic contaminants, resulting in the breakdown and detoxification of contaminants. In general the method optimizes environmental conditions by providing oxygen source and nutrients which are delivered to subsurface through an injection well or infiltration system to enhance microbial activity. Indigenous microorganisms can be generally be relied on to degraded wide variety of compounds by using proper nutrients and sufficient oxygen.

Table 3 summarizes organic groups subject to microbial metabolism by aerobic respiration, anaerobic respiration, and fermentation. These tables and estimation methods provide only a general indication of degradability of compounds. A treatability study will be required to determine degradability of specific waste components.

Table 4 provides relative degradabilities of various substances in terms of BOD_5/COD ratio. Higher ratio represents higher biodegradability.

Concentrations of inorganics and/or organic contaminants could be so high as to be toxic to the microbial populations. Table 5 lists concentrations at which certain compounds have been found to be toxic in industrial waste treatment. Microorganisms present in the subsurface may be more tolerant to high concentrations of these compounds. This determination must be made on case by case basis. A situation may prevail in which the contaminant concentrations are so low that the assimilative processes of microorganisms are sometimes not simulated, thus adaptation to the particular substrata will not occur and the substrata will not be degraded. It is also possible that even if the contaminants is present in acceptable concentrations, if there is another preferred carbon source available, the microorganisms will catabolize it preferentially.

The biodegradability of a compound at a low temperature may be much slower than at high temperature. Hence it may not be feasible to attempt a bioreclamation approach in the north.

TABLE 1. SUMMARY OF ORGANIC RESULTS OF THERMAL DESORPTION OF OLD MILL SOIL (AVERAGE)

Parameter	Untreated Soil, µg/kg	350°F µg/kg	% Reduction[1]	550°F µg/kg	% Reduction[1]
Volatile Organics					
Trichloroethene	2,400	173	93	<25	>99
Tetrachloroethene	362	35	90	<25	>93
Toluene	152	43	72	57	63
Xylenes (total)	950	285	70	48	95
Semivolatile Organics					
Aroclor 1260	2,000	3,000	(50)[2]	ND (100)[3]	>95

1 Reduction reported as % change from initial concentration, not corrected by moisture.

2 Increases in concentration are shown in parentheses.

3 ND (100) = Not detected (method detection limit).

TABLE 2. SUMMARY OF ORGANIC RESULTS OF THERMAL DESORPTION OF BERLIN-FARRO SOIL (AVERAGE)

Parameter	Untreated Soil, µg/kg	350°F µg/kg	% Reduction[1]	550°F µg/kg	% Reduction[1]
<u>Volatile Organics</u>					
2-Butanone	290	343[2]	(18)	80	72
Trichloroethene	147	<23	>84	<25	>83
Tetrachloroethene	280	<23	>92	3	99
Toluene	483	19	96	27	94
Xylenes (total)	387	<23	>94	<25	>91
<u>Semivolatile Organics</u>					
Hexachlorobutadiene	1,900 [3]	430 [3]	77	<3,300	NC [4]
Hexachlorocyclopentadiene	46,000	3,050	93	<3,300	93
Pentachlorobenzene	10,200	15,100	(48)	2,500	75
Hexachlorobenzene	105,000	250,000	(138)	47,000	55

[1] Reduction reported as % change from initial concentration, not corrected by moisture. Increases in concentration are shown in parentheses.

[2] Compound detected in the laboratory blank.

[3] Estimated values as presented by the CLP laboratory.

[4] NC = not calculated. The method detection limit of the analysis was exceeded by the laboratory; reduction cannot be calculated.

TABLE 3
SUMMARY OF ORGANIC GROUPS SUBJECT TO BIODEGRADATION

Substrate Compounds	Respiration		Fermentation	Oxidation	Co-oxidation
	Aerobic	Anaerobic			
Straight Chain Alkanes	+	+	+	+	+
Branched Alkanes	+	+	+	+	+
Saturated Aklyl Halides		+		+	+
Unsaturated Alkyl Halides		+		+	
Esters, Glycols, Epoxides	+	+	+	+	
Alcohols	+	+		+	
Aldehydes, Ketones	+	+		+	
Carboxylic Acids	+	+		+	
Amides	+	+			
Esters	+	+			
Nitriles	+	+			
Amines	+	+			
Phthalate Esters	+	+		+	
Nitrosamines		+			

(continued)

TABLE 3 (continued)

Substrate Compounds	Respiration		Fermentation	Oxidation	Co-oxidation
	Aerobic	Anaerobic			
Phenols - Dihydrides, Polyhydrides	+			+	+
Two & Three Ring Fused Polycyclic Hydrocarbons	+			+	
Biphenyls	+				
Chlorinated Biphenyls	+				
Four Ring Fused Polycyclic Hydrocarbons	+				
Five Ring Fused Polycyclic Hydrocarbons	+				
Fused Polycyclic Hydrocarbons	+				
Organophosphates	+	+			
Pesticides and Herbicides	+	+			+

.rce: Envirosphere, 1985

TABLE 3 (continued)

Substrate Compounds	Respiration: Aerobic	Respiration: Anaerobic	Fermentation	Oxidation	Co-oxidation
Thiols					
Cyclic Alkanes	+		+	+	+
Unhalogenated Aromatics	+	+		+	
Halogenated Aromatics	+	+		+	+
Simple Aromatic Nitro Compounds	+	+			
Aromatic Nitro Compounds With Other Functional Groups	+	+			+
Phenols	+	+	+	+	+
Halogenated Side Chain Aromatics	+		+	+	
Fused Ring Hydroxy Compounds	+				
Nitrophenols		+			
Halophenols	+			+	

(continued)

TABLE 4
BOD_5/COD RATIOS FOR VARIOUS ORGANIC COMPOUNDS

Compound	Ratio
Relatively Undegradable	
Butane	~ 0
Butylene	~ 0
Carbon tetrachloride	~ 0
Chloroform	~ 0
1,4-Dioxane	~ 0
Ethane	~ 0
Heptane	~ 0
Hexane	~ 0
Isobutane	~ 0
Isobutylene	~ 0
Liquefied natural gas	~ 0
Liquefied petroleum gas	~ 0
Methane	~ 0
Methyl bromide	~ 0
Methyl chloride	~ 0
Monochlorodifluoromethane	~ 0
Nitrobenzene	~ 0
Propane	~ 0
Propylene	~ 0
Propylene oxide	~ 0
Tetrachloroethylene	~ 0
Tetrahydronaphthalene	~ 0
1-Pentene	< 0.002
Ethylene dichloride	0.002
1-Octene	> 0.003
Morpholine	≤ 0.004
Ethylenediaminetetracetic acid	0.005
Triethanolamine	≤ 0.006
o-Xylene	< 0.008
m-Xylene	< 0.008
Ethylbenzene	< 0.009
Moderately Degradable	
Ethyl ether	0.012
Sodium alkylbenzenesulfonates	~ 0.017
Monoisopropanolamine	≤ 0.02
Gas oil (cracked)	~ 0.02
Gasolines (various)	~ 0.02
Moderately Degradable (cont'd.)	
Mineral spirits	~ 0.02
Cyclohexanol	0.03
Acrylonitrile	0.031
Nonanol	> 0.033
Undecanol	≤ 0.04
Methylethylpyridine	0.04-0.75
1-Hexene	< 0.044
Methyl isobutyl ketone	≤ 0.044
Diethanolamine	≤ 0.049
Formic acid	0.05
Styrene	> 0.06
Heptanol	≤ 0.07
sec-Butyl acetate	0.07-0.23
n-Butyl acetate	0.07-0.24
Methyl alcohol	0.07-0.73
Acetonitrile	0.079
Ethylene glycol	0.081
Ethylene glycol monoethyl ether	< 0.09
Sodium cyanide	≤ 0.09
Linear alcohols (12-15 carbons)	> 0.09
Allyl alcohol	0.091
Dodecanol	0.097
Relatively Degradable	
Valeraldehyde	≤ 0.10
n-Decyl alcohol	> 0.10
p-Xylene	< 0.11
Urea	0.11
Toluene	< 0.12
Potassium cyanide	0.12
Isopropyl acetate	≤ 0.13
Amyl acetate	0.13-0.34
Chlorobenzene	0.15
Jet fuels (various)	~ 0.15
Kerosene	~ 0.15
Range oil	~ 0.15
Glycerine	≤ 0.16
Adiponitrile	0.17
Relatively Degradable (cont'd.)	
Furfural	0.17-0.46
2-Ethyl-3-propylacrolein	< 0.19
Methylethylpyridine	< 0.20
Vinyl acetate	< 0.20
Diethylene glycol monomethyl ether	≤ 0.20
Naphthalene (molten)	≤ 0.20
Dibutyl phthalate	0.20
Hexanol	~ 0.20
Soybean oil	~ 0.20
Paraformaldehyde	0.20
n-Propyl alcohol	0.20-0.63
Methyl methacrylate	< 0.24
Acrylic acid	0.26
Sodium alkyl sulfates	~ 0.30
Triethylene glycol	0.31
Acetic acid	0.31-0.37
Acetic anhydride	≥ 0.32
Ethylenediamine	≤ 0.35
Formaldehyde solution	0.35
Ethyl acetate	≤ 0.36
Octanol	0.37
Sorbitol	≤ 0.38
Benzene	< 0.39
n-Butyl alcohol	0.42-0.74
Propionaldehyde	< 0.43
n-Butyraldehyde	≤ 0.43
Relatively Degradable (cont'd.)	
Ethyleneimine	0.46
Monoethanolamine	0.46
Pyridine	0.46-0.58
Dimethylformamide	0.48
Dextrose solution	0.50
Corn syrup	~ 0.50
Maleic anhydride	≥ 0.51
Propionic acid	0.52
Acetone	0.55
Aniline	0.56
Isopropyl alcohol	0.56
n-Amyl alcohol	0.57
Isoamyl alcohol	0.57
Cresols	0.57-0.68
Crotonaldehyde	< 0.58
Phthalic anhydride	0.58
Benzaldehyde	0.62
Isobutyl alcohol	0.63
2,4-Dichlorophenol	0.78
Tallow	~ 0.80
Phenol	0.81
Benzoic acid	0.84
Carbolic acid	0.84
Methyl ethyl ketone	0.88
Benzoyl chloride	0.94
Hydrazine	1.0
Oxalic acid	1.1

Source: Lyman, Reehl and Rosenblatt, 1982

TABLE 5
PROBLEM CONCENTRATIONS OF SELECTED CHEMICALS

Chemical	Problem Concentration (mg/l)	
	Substrate(1)	Non-Substrate(2)
n-Butanol	--	>1000
sec-Butanol	--	>1000
t-Butanol	>1000	>1000
Allyl alcohol	--	>1000
2-Ethyl-1-hexanol	500-1000	--
Formaldehyde	--	50-100
Crotonaldehyde	200	50-100
Acrolein	--	--
Acetone	--	>1000
Methyl isobutyl ketone	>1000	>1000
Isophorone	>1000	--
Diethylamine	--	300-1000
Ethylenediamine	--	100-300
Acrylonitrile	>1000	100
2-Methyl-5-ethylpyridine	>1000	100
N,N-dimethylaniline	>1000	--
phenol	>1000	300-1000
Ethyl benzene	>1000	--
Ethyl acrylate	600-1000	300-600
Sodium acrylate	--	>500
Dodecane	>1000	--
Dextrose	>1000	>1000
Ethyl acetate	>1000	--
Ethylene glycol	>1000	>900
Diethylene glycol	--	>1000
Tetraline	>1000	--
Karosene	--	>500
Cobalt chloride	--	>1000

(1)Substrate limiting reprsents the condition in which the subject compound is the sole carbon and energy source.
(2)Non-substrate limiting represents the condition in which other carbon and energy sources are present.

Source: SCS Engineers, 1979